SOME MEASUREMENTS OF MECHANICAL SUGARCANE HARVESTER PERFORMANCE

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Abstract

In the past three years several locally developed whole stalk harvesters and imported chopper harvesters have come into use in many areas of the South African sugar industry. The Experiment Station therefore conducted time and motion studies during the past two seasons to assess the performance of these harvesters while operating under local field and crop conditions.

The results of these studies show that harvester outputs vary considerably. The primary field, crop and management factors affecting both whole stalk and chopped cane harvester performances are discussed. Some of the more important issues that potential users of harvesting machines need to bear in mind, when endeavouring to derive optimum use from their machines, are highlighted. Future research requirements are also proposed.

Keywords: mechanisation, harvesting, performance.

Introduction

In South Africa sugarcane is grown under a wide range of conditions. These vary from steep to flat terrain, 0,9 to 1,5 m row spacing, 12 to 24 month cutting cycles and cultivation under dryland to flood and overhead sprinkler irrigation regimes. To affect the situation even more, only some mills are able to accept chopped cane.

During the past three years, several locally developed whole stalk harvesters and imported chopper harvesters have come into use in many areas of the South African sugar industry. The Experiment Station (SASEX) therefore conducted time and motion studies during the1997 and 1998 seasons to establish firstly, their performance under varying conditions and secondly, to determine the main factors affecting their performance and to identify future research requirements for the harvesting of sugarcane mechanically.

Method

"Time study is the basic technique of work measurement since it is concerned with the direct observation of work while it is performed." (Curry, 1963). Direct time study is best suited for repetitive operations such as ploughing, harrowing, sugarcane loading, transport and harvesting (Meyer and Worlock, 1982).

The technique used to study the various elements involved in the mechanical harvesting operations is the cumulative timing method. Time is recorded at the start and end of each element on a specially drawn up time study sheet (Table 1), using the lap recording facility commonly found on stopwatches. A typical field time study sheet used for mechanical harvesting operations is shown in Table 1.

Table 1. Example of field time study sheet.

Date: 12/6/98		**Machine:** Whole stalk			**Location:** North Coast		
Field No:	1024		**Crop condition:** Erect		**Soil type:**	Middle Ecca	
Cane variety:	NCo376		**Row spacing:** 1,2 m		**Soil condition:**	Dry	
Cane yield:	100 tons		**Row length:** 150 m		**Slope:**	6%	
Code	**Time**		**Remarks**	**Code**	**Time**		**Remarks**
	Minutes	**Seconds**			**Minutes**	**Seconds**	
1	9	59					
4	8	34	Topper jam				
1	8	25		4	23	48	No trailers
2	7	31	Steep bank	1	23	24	
1	5	48		2	14	56	
2	3	34		1	13	35	
1	2	20		2	11	15	
Start	0	00	**Continue**		9	59	
Code No:1 Harvesting Code No:2 Turning		Code No:3 Waiting for trailers Code No:4 Downtime		Code No:5 Code No:6			

Table 2. Typical bundle harvester time and motion output data.

Code	Total time	% time	No of observations	Average per observation (min)
1	22,02	39,61	5	4,04
2	11,37	20,45	5	2,27
3	8,28	14,90	2	4,14
4	13,92	25,04	1	13,92
Total	**55,58**	**100,00**		

In addition to the data shown in Table 1, field and crop conditions pertaining to each study as well as some general comments observed during the study were also recorded. Data recorded in the field are entered into a computer spreadsheet (Lotus 1-2-3 or MS Excel) to extract the total time and percent time for each element as depicted in Table 2.

The field performance of the individual harvesters is evaluated using the information shown in Table 2, together with the data collected in the field, such as row spacing, row length and cane yield.

Results and discussion

A total of 14 studies on two makes of locally developed bundle harvesters and 13 studies on three makes of chopper harvesters were undertaken. All the studies with the exception of two were conducted in burnt cane. In the case of the bundle harvester studies the cane was generally erect, whereas for the chopper harvester studies the degree of lodging ranged from 0 to over 90%. Summaries of the bundle and chopper harvester performances, ranked according to potential harvesting rate (t/h), are given in Tables 3 and 4 respectively.

Note:

Instantaneous harvesting and pour rate:
This represents the harvesting rate while the harvester is in motion and is affected by the speed of the harvester and cane and field conditions. This rate is calculated by dividing the cane tonnage harvested during the study period by the cutting time only.

Harvesting rate:
This represents the harvesting rate including all delays due to turning and waiting for transport. Harvesting rate is calculated by dividing the cane tonnage harvested during the study period by the total study time.

Potential harvesting rate:
This represents the harvesting rate, assuming no delays for transport. The potential harvesting rate is calculated by dividing the cane tonnage harvested during the study period by the harvesting/cutting time plus the turning time.

Field efficiency:
This is the harvesting/cutting time expressed as a percentage of the total study time.
The time taken for the machinery to travel to and from the fields is excluded from the time and motion studies.

As can be seen in Tables 3 and 4, the performances of the two types of harvesters vary considerably. The actual harvesting rates achieved during time and motion studies ranged between 7,7 and 39,8 t/h for the bundle harvesters and between 25,1 (green cane) and 51,8 t/h for the chopper harvesters. In the case of the whole stalk bundle type harvester, potential harvesting rates vary between 11,7 and 40,4

Table 3. Summary of bundle harvester performances.

	Harvester performance						
Study No:	**Av speed (km/h)**	Av turn time (min)	**Hours /ha**	**Inst. harvest rate (t/h)**	**Field eff. %**	**Harvest rate (t/h)**	**Pot. harvest rate (t/h)**
10	1,99	1,58	10,95	16,9	46,0	7,7	11,7
8	3,53	1,75	4,43	21,8	53,2	11,6	12,6
9	2,66	1,28	5,84	18,8	77,5	14,6	15,1
11	3,03	2,92	9,38	33,8	30,4	10,3	21,6
5	2,61	0,59	4,39	25,0	87,6	21,9	22,0
12	4,37	0,87	3,93	33,6	52,7	17,7	22,7
7	3,79	0,65	4,80	27,2	55,0	15,0	23,0
2	3,68	1,91	4,40	46,1	51,6	23,8	25,1
4	4,60	1,51	3,50	53,2	43,4	23,1	29,3
3	3,19	0,67	3,51	40,0	74,7	29,9	33,5
6	2,66	0,88	3,47	38,7	77,4	30,0	34,1
13	4,95	-	2,20	38,1	83,5	31,8	36,2
14	6,07	0,56	2,15	46,8	69,3	32,4	37,2
1	3,50	0,34	2,62	43,9	90,7	39,8	40,4

Inst. – instantaneous Eff. – efficiency Pot. – potential

Table 4. Summary of chopper harvester performances.

	Harvester performance						
Study No:	Av speed (km/h)	Av turn Time (min)	Hours /ha	Pour rate (t/h)	Field eff. %	Harvest rate (t/h)	Pot. harvest rate (t/h)
10 *	2,75	2,03	4,21	43,7	57,6	25,1	39,9
6 *	4,41	1,70	2,51	61,1	60,5	37,0	40,2
2	4,38	2,38	3,98	77,9	40,9	31,9	43,4
11	3,59	2,27	4,69	80,3	39,5	31,7	53,0
4	5,89	1,31	2,30	80,2	52,8	42,3	54,0
13	2,63	0,98	4,60	63,2	41,4	26,2	58,3
12	2,79	1,38	2,26	62,7	79,3	49,7	58,5
5	7,15	1,34	2,54	99,2	36,6	36,4	59,6
3	4,14	1,67	3,56	81,2	48,4	39,3	60,3
8	6,44	1,08	1,84	92,2	56,2	51,8	60,1
7	6,68	1,08	2,00	92,6	49,9	46,2	61,8
1	5,72	1,88	3,08	98,0	40,6	39,7	67,4
9	4,12	1,93	5,22	95,9	31,0	29,7	68,1

* Green cane

t/h, while for the chopper harvesters potential harvesting rates vary between 39,9 and 68,1 t/h. The studies show that average harvesting rates of the bundle type harvesters and chopper harvesters are about 22 t/h and 37 t/h respectively. These results are not unexpected bearing in mind the range of machines, crop and field conditions and operator proficiencies.

Care must be taken when interpreting the time and motion results. For example, when comparing the results obtained in Study 2 with those obtained in Study 6 in Table 4, the actual and potential outputs are fairly similar but field efficiencies are vastly different. The main reason for the low field efficiency in Study 2 was the amount of time the harvester spent waiting for the infield transport.

It must be noted that during these studies no attempt whatsoever was made to assess the quality of work performed by the various machines. The main purpose of the studies was to establish the performance range for each type of machine.

FACTORS AFFECTING HARVESTER PERFORMANCE

There are numerous factors affecting harvester performances (Meyer, 1997). The most important field and crop related factors include:

Terrain (steep versus flat)
Soil type and moisture level
Cane variety (brittle, loose leafed)
Cane yield
Cane condition (green or burnt and erect or recumbent)
Field condition (field layout, row spacing, row length, headland space, rocks)
Transport haulout distance
Number and capacity of infield transport
Operator proficiency
Machine condition and setting.

All the above factors will impact on the harvester's overall performance under the following headings:

- Harvesting time
- Turning time
- Downtime.

Harvesting time

Cane condition:
It should be noted that in the case of the whole stalk bundling harvesters none of the studies was conducted in high yielding fields, sprawled or lodged cane. This is because these machines often cannot operate effectively under such conditions. Furthermore, these machines can only harvest a single row of cane per pass and were not designed to harvest green cane.

On the other hand, the chopper harvesters can operate both in burnt and green cane, although the potential output in green cane is reduced by as much as 30-40% (Table 4, Studies 6 and 10). Furthermore, some of these machines are able to harvest two rows per pass and chopper harvesters are able to operate effectively in heavily lodged cane.

Operating speed:
Many of the abovementioned factors will influence harvester forward speed. Machines operating in heavily lodged green cane will certainly not have the same output as those working in erect burnt cane conditions. The results show that bundle harvester forward speeds ranged between 1,99 and 6,07 km/h in burnt cane, while chopper harvester forward speeds ranged from 2,75 to 7,15 km/h. Slope and field smoothness, especially the interrow, will also affect harvesting forward speed.

Turning time

Headlands:
As can be judged from Tables 3 and 4, the turning time can account for a large proportion of total time for both bundle

and chopper harvesters. In the case of the bundle type harvester, turning time is mainly dependent, other than width and condition of the headland, on machine length and the machine's general manoeuvrability.

In many cases, the chopper harvester requires considerably less time to turn than the infield transport, unless specialised transport vehicles are used. Generally, as far as chopper harvesting is concerned, the larger the capacity and the longer the infield transport, and the narrower and rougher the headland, the longer the turning time which can be expected.

Row spacing:
Row spacing and row length have a marked effect on overall mechanical harvester performance and this must be taken into account when estimating the daily and annual tonnage to be handled by the harvesting machinery. It has been clearly demonstrated that these two factors alone play a significant role in determining optimum machinery performance (Meyer, 1998).

Downtime

Waiting for trailers:
The number of infield haulage vehicles and their payload capacity as well as the haulout distance have an effect on harvester output (Ridge and Dick, 1985; Meyer, 1998). The effect of waiting for infield transport on harvester performance is clearly shown in Table 4, Studies 5 and 9. In Study 9, 52% of total time was spent waiting for infield transport compared with 38% for Study 5. Thus while the potential harvesting rate for Study 9 was 68 t/h versus 59 t/h for Study 5, the actual harvesting rate was lower.

Operators:
A well trained operator will operate his machine at maximum efficiency without over-stressing any part of it. Furthermore, the use of a skilled operator will ensure lower maintenance and repair costs and improve machine reliability, which would normally result in reduced overall harvesting costs.

Machine condition and setting

The operating condition and adjustment of the harvester will affect its overall performance (de Beer and Boevey, 1977). An example of this can be seen in Table 3, Studies No 7 and 10 where a poorly maintained or adjusted conveyor chain and topper resulted in over 80% and 50% downtime respectively.

Conclusions

Time and motion studies are an established method of assessing machinery performances. It has been shown that time studies can be used to predict actual field performance to within 20% accuracy (Murray and Meyer, 1982). Time and motion study results are useful measurements for setting performance standards for a wide range of farming operations and for mechanisation planning exercises.

Although only a limited number of time and motion studies were conducted on each type of cane harvester, the results nevertheless can be used as a useful guide for planning purposes. The results show that for whole stalk bundling harvesters the average actual harvesting rate is 22 t/h and, under reasonable field and crop conditions, one could expect to achieve between 20 and 30 t/h. In the case of chopper harvesters, the average actual harvesting rate is 37 t/h and under reasonable field and crop conditions one could expect to achieve between 30 and 45 t/h.

Existing and potential users of mechanical harvesting machinery will have to pay special attention to their land preparation operations, field layout designs, drainage and irrigation systems as well as cane transport systems to ensure high machinery outputs, efficiencies and acceptable operating costs.

Future research should include the role sugarcane varieties play as well as measurement of cane and harvesting losses associated with mechanical harvesting. Research should also include the effect that mechanical harvesting has on issues such as soil compaction and irrigation system designs. In addition, time and motion studies on harvesting machines operating on sloping terrain need to be carried out.

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